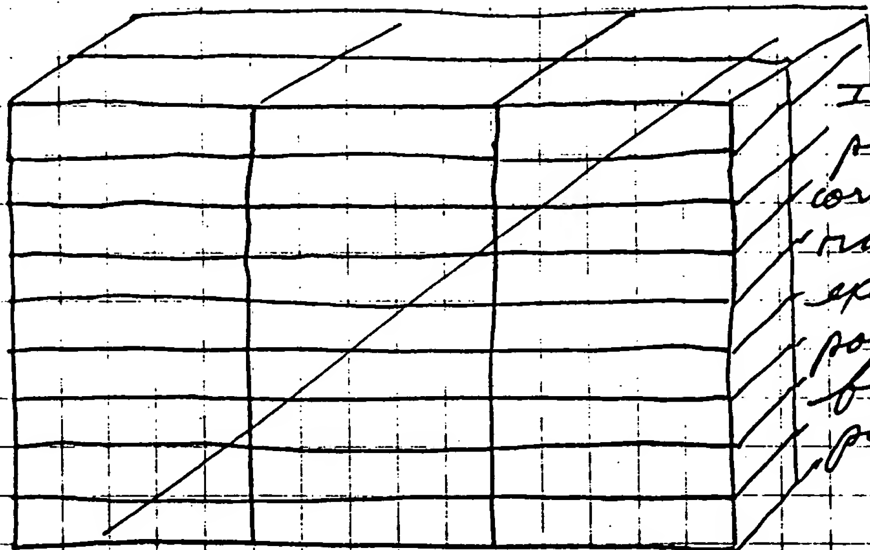
ASE & Parasitics

ATTACHMENT B

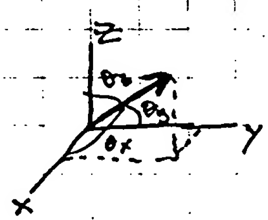


In this latt[ice] picture a par[ticle] corresponds to [a] ray ending u[p] exactly n lat[tice] positions removed from its orig[inal] position.

1. pick a direction vector
2. calculate reflection off 3 sets of orthogonal plan[es]
3. calculate travel distance between successf[ul] hits on a single set of planes
4. assign a loss/cm number

this looks amenable to an analytic treatment.

use direction cosines to parameterize ray direction



$$(\cos\theta_x, \cos\theta_y, \cos\theta_z) = \frac{(RND1, RND2, RND3)}{\sqrt{RND1^2 + RND2^2 + RND3^2}}$$

Let Δx, Δy, and Δz denote slab dimensions or plane spacing.

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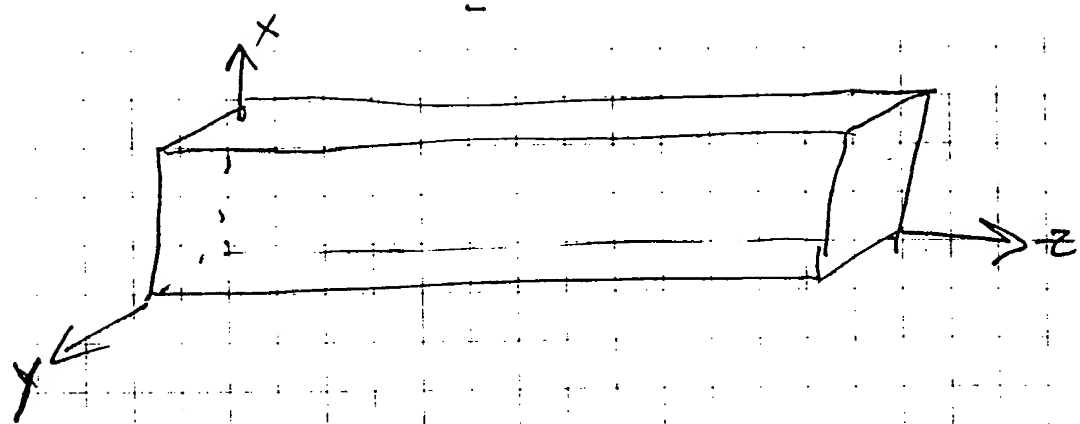
From this point of view it doesn't matter what position a ray is launched from, only its direction, because launch position has no impact on spacing between plan[e] strikes.



Treat cants on surface perturbatively.

2 questions:

① How big do cants have to be to eliminate all parasitics?

② For a rectangular slab, how close to slab index does cladding index have to be to eliminate all parasitics.

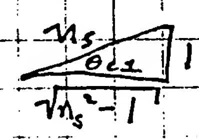
This question will be easiest to answer for a zero loss parasitic

set z face incident angle equal to $\theta_{crit1} = \sin\left(\frac{1}{n_s}\right)$ and the x face hit and y face hit also $= \theta_{crit2} = \sin^{-1}\left(\frac{n_c}{n_s}\right)$

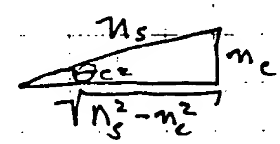
make this argument more rigorous!

Now work with direction cosines

$$\theta_{c1} = \sin^{-1}\left(\frac{1}{n_s}\right)$$



$$\theta_{c2} = \sin^{-1}\left(\frac{n_c}{n_s}\right)$$



$$\cos\theta_{c1} = \frac{\sqrt{n_s^2-1}}{n_s}$$

$$\cos\theta_{c2} = \frac{\sqrt{n_s^2-n_c^2}}{n_s}$$

$$\cos^2\theta_{c1} + 2\cos^2\theta_{c2} = 1$$

$$\frac{n_s^2-1}{n_s^2} + \frac{2(n_s^2-n_c^2)}{n_s^2} = 1$$

$$\cancel{n_s^2} - 1 + 2n_s^2 - 2n_c^2 = \cancel{n_s^2}$$

$$2(n_s^2 - n_c^2) = 1$$

$$n_s^2 - n_c^2 = \frac{1}{2}$$

when can this no longer be solved

$$n_c = \sqrt{n_s^2 - \frac{1}{2}}$$

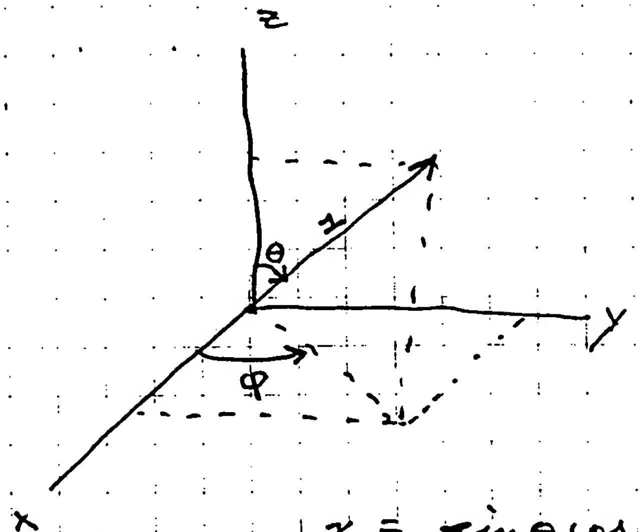
$$n_c = \sqrt{1.82^2 - \frac{1}{2}} = \underline{\underline{1.677}}$$

for $n_c > 1.677$ no zero loss parasitics exist!

this agrees with code: Slab ASE 02.XCL prediction

Question 2 will be easiest to answer numerically by finding the angular width over which a parasitic exists for given gain and cladding indices.

7-sep-97



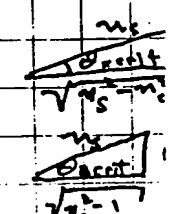
$x = \sin\theta \cos\varphi = \cos\theta_x$
$y = \sin\theta \sin\varphi = \cos\theta_y$
$z = \cancel{\cos\varphi\theta}\ \cos\theta = \cos\theta_z$

$\left.\begin{array}{l}\theta_x < \theta_{x\,crit}\\ \theta_y < \theta_{y\,crit}\\ \theta_z < \theta_{z\,crit}\end{array}\right\}$ to avoid 0-loss parasitics

$\cos^2\theta_x + \cos^2\theta_y + \cos^2\theta_z = 1$

$\left.\begin{array}{l}\cos\theta_x > \cos\theta_{x\,crit}\\ \cos\theta_y > \cos\theta_{y\,crit}\\ \cos\theta_z > \cos\theta_{z\,crit}\end{array}\right\}$ to avoid 0-loss parasitics

$\sin\theta_{x\,crit} = \frac{n_c}{n_s}$
$\sin\theta_{y\,crit} = \frac{n_c}{n_s}$
$\sin\theta_{z\,crit} = \frac{1}{n_s}$



$\left.\begin{array}{l}\cos\theta_x > \frac{\sqrt{n_s^2-n_c^2}}{n_s}\\ \cos\theta_y > \frac{\sqrt{n_s^2-n_c^2}}{n_s}\\ \cos\theta_z > \frac{\sqrt{n_s^2-1}}{n_s}\end{array}\right\}$ to avoid 0-loss parasitics

$1 = \cos\theta_x^2 + \cos\theta_y^2 + \cos\theta_z^2$ and this must be greater than

$$\boxed{1 > \frac{n_s^2-n_c^2}{n_s^2} + \frac{n_s^2-n_c^2}{n_s^2} + \frac{n_s^2-1}{n_s^2}}$$ to avoid 0-loss parasitics

n_s is slab index
n_c is coating index

$$1 > \frac{3n_s^2 - 2n_c^2 - 1}{n_s^2}$$

$$n_s^2 > 3n_s^2 - 2n_c^2 - 1$$

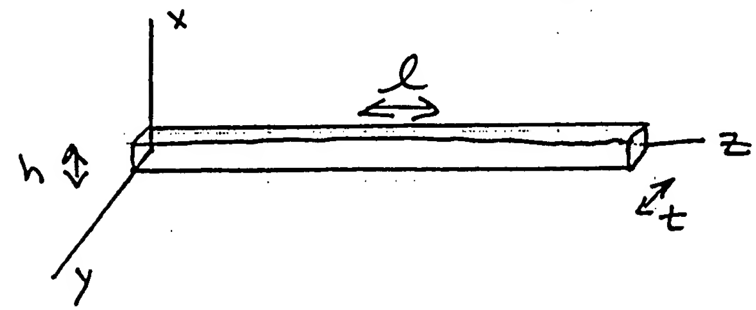
$$1 > 2(n_s^2 - n_c^2)$$

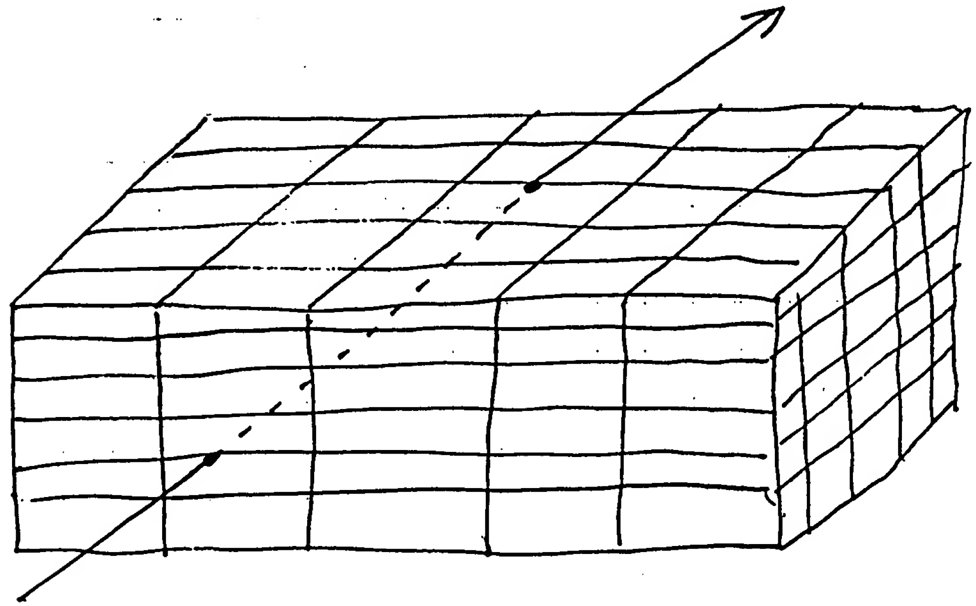
$$\frac{1}{2} > n_s^2 - n_c^2$$

$$n_c^2 > n_s^2 - \frac{1}{2}$$

$$n_c > \sqrt{n_s^2 - \frac{1}{2}} = \sqrt{1.82^2 - \frac{1}{2}} = 1.677$$

using a "method of images" construction





fill space using slab and slab images

- define arbitrary ray direction using direction cosines ($\cos\theta_x$, $\cos\theta_y$, $\cos\theta_z$)
- Gain of ray is given in nepers/cm by

$$g = \frac{\ln(\mathrm{Ref}x)}{(h/\cos\theta_x)} \quad \frac{\ln(\mathrm{Ref}y)}{(t/\cos\theta_y)} \quad \frac{\ln(\mathrm{Ref}z)}{(l/\cos\theta_z)} \quad \alpha$$

where: Ref i is the reflection coefficient for i-oriented planes
α is slab specific gain loading

zero-loss parasitics correspond to those ray directions that are confined by TIR at all three sets of planes

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$$\text{TIR condition} \begin{cases} \cos\theta_x < \cos\theta_{x\text{-crit}} = \dfrac{\sqrt{n_s^2 - n_c^2}}{n_s} \\ \cos\theta_y < \cos\theta_{y\text{-crit}} = \dfrac{\sqrt{n_s^2 - n_c^2}}{n_s} \\ \cos\theta_z < \cos\theta_{z\text{-crit}} = \dfrac{\sqrt{n_s^2 - 1}}{n_s} \end{cases}$$

where:
n_s = slab index
n_c = coating index

- since $1 = \cos\theta_x^2 + \cos\theta_y^2 + \cos\theta_z^2$, zero loss parasitics exist when

$$1 < \frac{n_s^2 - n_c^2}{n_s^2} + \frac{n_s^2 - n_c^2}{n_s^2} + \frac{n_s^2 - 1}{n_s^2}$$

or

$$n_c < \sqrt{n_s^2 - 1/2}$$

zero-loss parasitics can be completely suppressed by choosing a cladding with refractive index large enough

$$n_c > \sqrt{n_s^2 - 1}$$